

We claim:

1. A method of supplying tap weights to taps
of a decision feedback equalizer comprising:

5 determining a channel impulse response of a
channel through which the decision feedback equalizer
receives a signal;

determining constrained tap weights based on
the channel impulse response and a differentiable tap
10 weight constraint function, wherein the differentiable
tap weight constraint function is an approximation of a
non-differentiable tap weight constraint function; and,

supplying the constrained tap weights to the
decision feedback equalizer.

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2. The method of claim 1 wherein the
differentiable tap weight constraint function comprises
an approximation of a 1-norm tap weight constraint
function.

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3. The method of claim 1 wherein the decision
feedback equalizer comprises a feed forward filter having
feed forward taps and a feedback filter having feedback
taps, wherein the determining of constrained tap weights
5 comprises (i) determining constrained tap weights for the
taps of the feedback filter based on the differentiable
tap weight constraint function and (ii) determining
unconstrained tap weights for the taps of the feed
forward filter, and wherein the supplying of the
10 constrained tap weights to the decision feedback
equalizer comprises (i) supplying the constrained tap
weights to the feedback filter and (ii) supplying the
unconstrained tap weights to the feed forward filter.

15 4. The method of claim 3 wherein the
differentiable tap weight constraint function comprises
an approximation of a 1-norm tap weight constraint
function, and wherein the differentiable tap weight
constraint function comprises a function of the feedback
20 taps.

5. The method of claim 1 wherein the determining of a channel impulse response comprises determining the channel impulse response and a signal-to-noise ratio characterizing the channel, and wherein
5 determining of constrained tap weights comprises determining the constrained tap weights based on the channel impulse response, the signal-to-noise ratio, and the differentiable tap weight constraint function.

10 6. The method of claim 5 wherein the differentiable tap weight constraint function comprises an approximation of a 1-norm tap weight constraint function.

15 7. The method of claim 5 wherein the decision feedback equalizer comprises a feed forward filter having feed forward taps and a feedback filter having feedback taps, wherein the determining of constrained tap weights comprises (i) determining constrained tap weights for the
20 taps of the feedback filter based on the differentiable tap weight constraint function and (ii) determining unconstrained tap weights for the taps of the feed forward filter, and wherein the supplying of the

constrained tap weights to the decision feedback equalizer comprises (i) supplying the constrained tap weights to the feedback filter and (ii) supplying the unconstrained tap weights to the feed forward filter.

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8. The method of claim 7 wherein the modified tap weight constraint function comprises a 1-norm tap weight constraint function, and wherein the differentiable tap weight constraint function comprises a
10 function of the feedback taps.

9. The method of claim 1 wherein the differentiable tap weight constraint function is given by the following expression:

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$$\sum_{m=0}^{N_{FB}} f(g[m]) \leq M$$

wherein $f(g[m])$ is given by the following expression:

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$$f(x) = \begin{cases} |x| & \text{if } |x| \geq \gamma \\ f_0 + f_2 x^2 + f_4 x^4 & \text{if } |x| < \gamma \end{cases}$$

wherein $x = g[m]$, wherein $g[m]$ are the tap weights,
wherein N_{FB} are the number of the taps, and wherein γ , M ,
 f_0 , f_2 , and f_4 are selected values.

- 5 10. The method of claim 9 wherein $M = 1, 2$, or
3, $\gamma = M/1000$, $f_0 = 3\gamma / 8$, and wherein f_2 and f_4 are
determined in accordance with the following expressions:

$$f_2 = \frac{3}{2\gamma} - 2 \frac{f_0}{\gamma^2}$$
$$10 \quad f_4 = \frac{1}{\gamma^4} \left(f_0 - \frac{\gamma}{2} \right).$$

11. The method of claim 1 wherein the decision
feedback equalizer comprises a feed forward filter having
feed forward taps and a feedback filter having feedback
15 taps, wherein the differentiable tap weight constraint
function is given by the following expression:

$$\sum_{m=0}^{N_{FB}} f(g_B[m]) \leq M$$

- 20 wherein $f(g_B[m])$ is given by the following expression:

$$f(x) = \begin{cases} |x| & \text{if } |x| \geq \gamma \\ f_0 + f_2 x^2 + f_4 x^4 & \text{if } |x| < \gamma \end{cases}$$

wherein $x = g_B[m]$, wherein $g_B[m]$ are the tap weights of the feedback taps, wherein N_{FB} are the number of the
5 feedback taps, and wherein γ , M , f_0 , f_2 , and f_4 are selected values.

12. The method of claim 11 wherein $M = 1, 2$, or 3, $\gamma = M/1000$, $f_0 = 3\gamma / 8$, and wherein f_2 and f_4 are
10 determined in accordance with the following expressions:

$$f_2 = \frac{3}{2\gamma} - 2 \frac{f_0}{\gamma^2}$$
$$f_4 = \frac{1}{\gamma^4} \left(f_0 - \frac{\gamma}{2} \right).$$

13. A decision feedback equalizer comprising:
a feed forward filter that applies feed forward
taps to a signal to be equalized, wherein the signal to
be equalized is based on transmitted symbols;
5 a
decision device;
a feedback filter that applies feedback taps to
an output of the decision device;
a summer that sums outputs from the feed
10 forward filter and the feedback filter to provide the
output of the decision feedback equalizer, wherein the
output of the decision feedback equalizer is provided to
the decision device; and,
a tap weight determiner that determines
15 constrained tap weights and unconstrained tap weights in
response to the output of the decision device and the
signal to be equalized in order to minimize the mean
squared error between the transmitted symbols and the
output of the decision feedback equalizer, wherein the
20 constrained tap weights are determined by constraining
the minimum mean squared error subject to a tap weight
constraint function, wherein the tap weight constraint
function is differentiable and is an approximation of a

non-differentiable tap weight constraint function, and
wherein the tap determiner supplies the constrained tap
weights to the taps of the feedback filter and the
unconstrained tap weights to the taps of the feed forward
5 filter.

14. The decision feedback equalizer of claim
13 wherein the tap weight constraint function comprises
an approximation of a 1-norm tap weight constraint
10 function of the feedback taps.

15. The decision feedback equalizer of claim
13 wherein the tap weight constraint function is given by
the following expression:
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$$\sum_{m=0}^{N_{FB}} f(g_B[m]) \leq M$$

wherein $f(g_B[m])$ is given by the following expression:

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$$f(x) = \begin{cases} |x| & \text{if } |x| \geq \gamma \\ f_0 + f_2 x^2 + f_4 x^4 & \text{if } |x| < \gamma \end{cases}$$

wherein $x = g_B[m]$, wherein $g_B[m]$ are the tap weights of the feedback taps, wherein N_{FB} are the number of the feedback taps, and wherein γ , M , f_0 , f_2 , and f_4 are selected values.

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16. The decision feedback equalizer of claim 15 wherein $M = 1, 2$, or 3 , $\gamma = M/1000$, $f_0 = 3\gamma/8$, and wherein f_2 and f_4 are determined in accordance with the following expressions:

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$$f_2 = \frac{3}{2\gamma} - 2 \frac{f_0}{\gamma^2}$$
$$f_4 = \frac{1}{\gamma^4} \left(f_0 - \frac{\gamma}{2} \right).$$

17. The decision feedback equalizer of claim 15 13 wherein the tap weight determiner includes a channel impulse response estimator and a tap weight calculator, wherein the channel impulse response estimator determines a channel impulse response for a channel through which the signal is received, wherein the tap weight calculator 20 determines the constrained tap weights and the unconstrained tap weights in response to the output of

the decision device and the signal to be equalized in order to minimize the mean squared error between the transmitted symbols and the output of the decision feedback equalizer.

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18. The decision feedback equalizer of claim 17 wherein the tap weight constraint function comprises an approximation of a 1-norm tap weight constraint function of the feedback taps.

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19. The decision feedback equalizer of claim 17 wherein the tap weight constraint function is given by the following expression:

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$$\sum_{m=0}^{N_{FB}} f(g_B[m]) \leq M$$

wherein $f(g_B[m])$ is given by the following expression:

$$f(x) = \begin{cases} |x| & \text{if } |x| \geq \gamma \\ f_0 + f_2 x^2 + f_4 x^4 & \text{if } |x| < \gamma \end{cases}$$

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wherein $x = g_B[m]$, wherein $g_B[m]$ are the tap weights of the feedback taps, wherein N_{FB} are the number of the feedback taps, and wherein γ , M , f_0 , f_2 , and f_4 are selected values.

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20. The decision feedback equalizer of claim 19 wherein $M = 1, 2$, or 3 , $\gamma = M/1000$, $f_0 = 3\gamma / 8$, and wherein f_2 and f_4 are determined in accordance with the following expressions:

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$$f_2 = \frac{3}{2\gamma} - 2 \frac{f_0}{\gamma^2}$$
$$f_4 = \frac{1}{\gamma^4} \left(f_0 - \frac{\gamma}{2} \right).$$

21. A method of supplying tap weights to taps
15 of a decision feedback equalizer comprising:

determining a channel impulse response of a channel through which the decision feedback equalizer receives a signal;

estimating an error at the output of the
20 decision feedback equalizer;

determining a constraint value M as a function
of the estimated error;

determining constrained tap weights based on
the channel impulse response and a tap weight constraint
5 function having the constraint value M ; and,

supplying the constrained tap weights to the
decision feedback equalizer.

22. The method of claim 21 wherein the tap
10 weight constraint function comprises a differentiable
approximation of a 1-norm tap weight constraint function.

23. The method of claim 21 wherein the
decision feedback equalizer comprises a feed forward
15 filter having feed forward taps and a feedback filter
having feedback taps, wherein the determining of
constrained tap weights comprises (i) determining
constrained tap weights for the taps of the feedback
filter based on the tap weight constraint function and
20 (ii) determining unconstrained tap weights for the taps
of the feed forward filter, and wherein the supplying of
the constrained tap weights to the decision feedback
equalizer comprises (i) supplying the constrained tap

weights to the feedback filter and (ii) supplying the unconstrained tap weights to the feed forward filter.

24. The method of claim 23 wherein the tap
5 weight constraint function comprises a differentiable approximation of a 1-norm tap weight constraint function of the feedback taps.

25. The method of claim 21 wherein the
10 determining of a constraint value M as a function of an output of the decision feedback equalizer comprises determining the constraint value M as a linear function of the output of the decision feedback equalizer.

15 26. The method of claim 21 wherein the determining of a constraint value M as a function of an output of the decision feedback equalizer comprises determining the constraint value M as a first linear function when the mean squared error between the received
20 signal and the output of the decision feedback equalizer is below a threshold Th_L and as a second linear function when the mean squared error between the received signal

and the output of the decision feedback equalizer is
above a threshold Th_H .

27. The method of claim 26 wherein the first
5 linear function has a proportionality constant α , wherein
the second linear function has a proportionality constant
 β , and wherein the proportionality constants α and β
are equal.

10 28. The method of claim 26 wherein the first
linear function has a proportionality constant α , wherein
the second linear function has a proportionality constant
 β , and wherein the proportionality constants α and β
are unequal.

15 29. The method of claim 21 wherein the
estimating of an error at the output of the decision
feedback equalizer comprises estimating a mean squared
error at the output of the decision feedback equalizer.

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